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Agricultural Research Administration
Bureau of Plant Industry, Soils
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H. T. & S. Office Report No. 202

Report On Spinach Prepackaging Tests - 1948

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Report of a study made under the
Research and Marketing Act of 1946
Project No. 44

Division of Fruit and Vegetable Crops and Diseases

February 28, 1949
Beltsville, Maryland

Report On Spinach Prepackaging Tests 1948

Introduction

Of all prepackaged fresh produce items, spinach is second in volume only to tomatoes. In Los Angeles more than 50 percent of the spinach marketed in 1945 was handled in transparent consumer units (1), while in New York City during 1945, 12 percent of the spinach marketed was prepackaged (2). Prepackaging of spinach has increased greatly up to the present time and although there is no definite figure for 1948, undoubtedly a large proportion was marketed in this way.

The extent of the spinach prepack is good evidence that both the modern retail merchandiser with self service techniques, and the consumer have a desire for spinach trimmed, washed, and in a transparent bag. Stimulated by the overwhelming acceptance of the pack the industry has grown tremendously. Spinach has been called a "natural" for prepackaging and the following reasons may be given for the enthusiastic acceptance by the trade:

1. It offers the modern super-market a consumer unit and does away with weighing and bagging at the produce counter.
2. It keeps the produce counter tidy, does away with scattered leaves, picked over leaves, and wilted leaves.
3. Transparent, shiny bags have greater eye appeal and serve to increase sales.
4. It is easier for the trade to handle bags and master cartons, in contrast to bushel baskets and hampers with ice in them. Causes less mess.
5. Many spinach prepackers date their bags and pick up old spinach bags at no loss to the retailers. This helps control quality.

Consumer preference is based on the following factors:

1. The spinach has been sorted, trimmed, washed, and is ready to cook.
2. It offers a more sanitary method of merchandising.
3. Improved appearance makes purchase of spinach more desirable.
4. Brand names are used by packers, which allows consumers to select brands of known quality. (This serves as a stimulus for quality control.)
5. Dated bags indicate age of spinach package.
6. Consumer units shorten time required for shopping.

Except for the summer months, when many other green vegetables are available, the demand for spinach and its production are rather stable throughout the year (1). This results in a balance of supply and demand and enables packaging to be carried on the year round. Even during the period when local bulk spinach is in competition with prepackaged spinach there is generally a preference for the prepackaged spinach, even though it demands a higher price. Some of the price differential is accounted for by waste that must be trimmed from the bulk spinach by the consumer. Rasmussen and Platenius (3) state that a pound of prepackaged spinach is equivalent to approximately 2.5 lbs. of bulk spinach.

The spinach packaging problems are principally those of improved methods of packaging, handling and refrigerating. Since most stores do not have facilities for refrigerating prepackaged spinach, the prepackers are most anxious to improve the method of handling so that good quality will be maintained and the marketing period extended.

Experimental Studies

In the spring of 1948 studies on prepackaged spinach were carried on in cooperation with E. L. Duvall and Sons, Inc., spinach packers in Baltimore, Maryland. The following three aspects were considered in these studies:

1. The effect of treatment with an antiseptic, before bagging, on the control of bacterial soft rot.
2. The effect of different types of film on the weight loss, O_2 and CO_2 relationships, and percentage of decay at different temperatures for varying periods.
3. The effects of prepackaging and storage in different types of films and at different temperatures for varying periods on the Vitamin C content.

Antiseptic Treatments

Previous work had suggested that chlorine might be effective in reducing the percentage of breakdown in prepackaged vegetables. It was thought that chlorine added during the washing operation might reduce subsequent decay. The antiseptic used was a commercial bleaching agent, which is a concentrated sodium hypochlorite solution (NaClO). Determinations of chlorine in the solution, using a sodium thiosulfate ($Na_2S_2O_3$) starch iodine titration showed the solution to contain 59,140 parts per million of chlorine. Dilutions were made to obtain solutions of approximately 100 p.p.m., 1,000 p.p.m., 3,000 p.p.m., 5,000 p.p.m., and 10,000 p.p.m. These solutions were used as dips and the spinach was examined after holding at 70° F. for 2 and 3 days.

The spinach was obtained in bushel baskets as received at the Duvall prepackaging plant and taken to the laboratory at Beltsville. The leaves were washed, with a hose, to remove sand, insects, grit, etc. and then five pounds, enough for approximately 5 bags, were soaked in each chlorine solution for fifteen minutes. They were then removed from the dip, the excess water removed by centrifuging and packaged in cellophane bags. All lots were treated alike, except for the concentration of Cl_2

in the solutions. Samples for bacterial counts were taken before and after each treatment from both leaves and solutions. The solutions were titrated before and after soaking to determine reduction in chlorine concentration during treatment.

After two days at 70° F. the bagged lots from each treatment were opened and sorted. All leaves with any decay whatever, no matter how small the affected area, were discarded. These decayed leaves were weighed and the percentage of decayed leaves was determined. The results are summarized in table 1.

Table 1. — Results of dipping spinach in solutions of various chlorine concentrations.

These data indicate that chlorine greatly reduces the number of organisms infesting spinach leaves, but not sufficiently to control decay within the packages. The data in table 2 summarize the reduction in number of organisms per gram of tissue as a result of washing in different concentrations of chlorine.

Table 2. — Result of chlorine treatments on number of organisms and occurrence of decay.

There is a considerable percentage decrease in the number of microorganisms in one gram of leaf tissue with increase in chlorine concentration. Five thousand five hundred p.p.m. of chlorine reduced the number of viable organisms infesting one gram of spinach 99.9 percent. The number of organisms remaining on one gram of spinach after washing with top water was 14.7 percent of the number present on the unwashed leaves. However, the large percentage of reduction of organisms did not cause similar reduction in the percentage of decayed leaves. While only 14.7 percent of the organisms originally present on the leaf were left after washing, 77.6 percent of the leaves showed decay. After two days at 70° F., treatments 2, 3, 4, and 5, with concentrations of 100, 1,100, 3,500 and 5,500 p.p.m. had 3.4 percent, 0.4 percent, 0.16 percent, and 0.11 percent of the organisms left after dipping, and 79.7, 88.3, 36.7, and 40.4 percent respectively of the leaves had decayed areas. Treatment 6, with 11,000 p.p.m. produced extensive injury and after 2 days at 70°F. 88 percent of the leaves were discarded due to injury and decay.

Chlorine in concentrations as high as 1,100 p.p.m. had no effect on decay development. However, 3,500 and 5,000 p.p.m. of chlorine reduced decay to approximately 40 percent, and showed only slight tissue injury affecting 3 - 10 percent of the leaves. It was noted that while the spinach that received treatments 1, 2, and 3 had a strong putrid odor, the usual odor associated with soft rot, this odor was lacking after treatments 4, 5 and 6.

After three days at 70° F. the spinach from all treatments was badly decayed and there was no marked difference between any of the treatments and the control. At this temperature, decay progressed so rapidly that even in those lots treated with the high concentrations of chlorine, all the leaves were affected in the three day period.

In conclusion it may be said that an extensive reduction took place in the percentage of decay in treatments with 3,500 p.p.m. and 5,500 p.p.m. as compared to the other treatments. There was half as much decay after two days at 70° F. with treatments 4 and 5 as with treatments 1, 2 and 3. However, the decay was not controlled sufficiently to result in a material lengthening of the marketable period of the packages.

The spinach used in these tests was generally of poor quality and seemed to have a great abundance of surface organisms. In spite of the 99.8 percent and 99.9 percent reduction in organisms per gram of tissue after treatment with 3,500 p.p.m. and 5,500 p.p.m. of chlorine, there still remained approximately 1,000,000 organisms per gram and 700,000 organisms per gram respectively. Millions of organisms were present on the spinach leaves even after treatment with more than 10,000 p.p.m. of chlorine. Though most of the organisms present probably would not cause decay, there were still enough decay producing organisms and tissue wounds to result in complete decay of the spinach in 3 days.

Only a sterile package can be expected to be free of decay. This is unattainable unless the decay producing organisms are destroyed or are continually inhibited by a bacteriostatic or mycostatic substance included in the package and in constant contact with these organisms. Such a material must be harmless to humans, have a non-objectionable odor, and have no affect on the natural flavor. Until such a material is found reliance for decay control must continue to be placed on use of good sanitation and effective refrigeration.

The Effect of Different Types of Films on Weight Loss, O_2 and CO_2 Relationships, and Keeping Quality of Spinach at Different Temperatures

The purpose of these tests was to compare the suitability of different types of films for prepackaging spinach. Table 3 shows the six films representing different moistureproof types and different gauges commonly available commercially that were used. Half of the bags of each film used were perforated. Bags of cellulose acetate, the most permeable film commonly used, were not available and therefore not included in the test.

Table 3. — List of films used in spinach prepackaging tests.

Procedure

Spinach was commercially packaged in bags made up of the six different films. Half of the bags of each film were perforated with two 1/4 inch holes on top of the bag, and two 1/4 inch holes in the middle. The bags were all staple closed. They were placed in ventilated shipping cartons and hauled to Beltsville where each bag was weighed and stored.

The spinach used in this test was of the Long Standing Bloomsdale variety grown in Pennsylvania in the early spring. It had been freshly cut and trucked to Baltimore and appeared to be of very good quality.

Twelve bags of each film, half perforated and half non-perforated, were stored at 70° F., 40° F., and 32° F. The group in 70°F. was examined after 24 and 48 hours, while the 40° F. and 32° F. lots were examined after one and three weeks in storage. Observations were made on the following factors:

a. Weight loss
b. CO_2 in bag atmosphere
c. O_2 in bag atmosphere
d. Percentage decay

The bags were weighed on removal from storage to determine percentage weight loss. The CO_2 and O_2 percentages in the atmosphere of the bags were determined with an Orsat gas analyzer. After gas determinations, each bag was opened and the odor noted. The decayed leaves were separated from the sound leaves and weighed. Leaves with any decay were considered in the decayed group. No attempt was made to cut around decayed areas even though in some cases only one small part of the leaf was affected.

A second test was carried out nine days later in which the procedure was exactly the same as in the first test. The spinach in the second test was of the same variety, and was grown in Maryland. It did not appear to be as fresh or to have as good quality as the spinach in the first test.

Results

Weight Loss

The weight loss of the spinach bags in the two tests are shown in table 4. Pliofilm, the rubber hydrochloride film, was the most moisture-proof film in both tests, 450 MSAT 86 and 87 were next and were very close to each other, 300 PBDS was fourth, 450 LSAT fifth, and 300 LSAT sixth. These five films are all different types of cellophanes. The perforated films behaved very much like their non-perforated counterparts exhibiting similar moisture losses at the same temperatures for like periods of storage.

Table 4. — Percent weight loss of spinach packaged in different films.

Table 4 shows percent losses in weight of the different bags after various periods of storage at different temperatures. The LSAT films lost two to three times as much as the Pliofilm and MSAT films. Ordinarily a weight loss of 0.5 - 2.0 percent is permissible. However, the perforated 300 LSAT packages had lost 5 to 9 percent of their weight after 2 and 3 weeks at 40° F. and 3 and 4.5 percent after two and three weeks at 32°. This loss is considered critical and caused some leaves to wilt. The 450 LSAT film lost about 1 percent less than the 300 LSAT film at the low temperatures.

Carbon Dioxide and Oxygen in Bag Atmospheres in Different Films

The CO_2 and O_2 in the atmospheres of the bags were determined with an Orsat gas analyzer. Scotch tape was sealed around the point of puncture of the bag to prevent air diffusion while taking a sample. All samples were handled similarly. Table 5 summarizes the average CO_2 percentages at different temperatures and storage periods in the two tests. In all cases CO_2 in the perforated films was far below that in the non-perforated films. After 2 days at 70°F., the highest concentrations of CO_2 were within the non-perforated Pliofilm bags, and averaged 16.4 percent in test 2. CO_2 within the different types of cellophane bags varied from 4.2 to 9.7 percent in the two tests. Some accumulation of CO_2 occurred within the ventilated bags, probably due to partial closure of perforations by leaf tissue and to accumulation of the CO_2 in the bottoms of the bags. This percentage varied from 1.5 percent in cellophane to 3.6 percent in Pliofilm.

Table 5. — Percent CO_2 accumulation in prepackaged spinach in which bags of different films were used.

Carbon dioxide concentration was progressively less at the temperatures of 40° and 32°F. After 3 weeks at 32°, cellophane bags of spinach contained CO_2 varying from 0.7 to 2.0 percent while in Pliofilm bags, CO_2 averaged 5.8 percent. The variation between the build-up of CO_2 within MSAT, LSAT and PBDS films in test 2 and test 1 is probably due to the difference in sealing obtained in the two tests.

The average O_2 percentages within the bags of spinach at each temperature, for the different storage periods are shown in table 6.

Table 6. — Percent of O_2 in prepackaged spinach in which bags of different films were used.

Only in the sealed Pliofilm bags at 70° F. did the O_2 go down to a dangerously low level. The perforated bags all maintained a percentage of O_2 averaging about 15 percent.

Generally the difference in the degree of tightness of the seal will vary between bags. This is true since there may not be complete sealing, and the amount of folding, the angle of folding, and the number of staples in each bag may vary. With the variation in seal there will also be a variation in CO_2 and O_2 diffusion through the bag. The leaks due to various causes may more than offset the differences in gas permeability between the various types of films. The permeability of each film to moisture was consistent in both tests. However, there was no such consistent differences between films with reference to gas diffusion. The rate of CO_2 evolution, openings through which diffusion can take place, and the type of film, all determine the CO_2 and O_2 concentrations within the package.

Effect of Carbon Dioxide in Bag on Flavor

Taste tests were conducted and no objectionable flavors could be detected in the spinach stored at 40° F. and 32° F. for one and two weeks. CO_2 at these temperatures was below 5 percent except in Pliofilm in which the CO_2 went up to 8.2 percent. After 30 hours at 70° no objectional flavor was noted in the cooked spinach from bags containing up to 12 percent CO_2 . The spinach in bags with CO_2 above 10 percent appeared greener and fresher than spinach in perforated bags with low CO_2 (approximately 1 percent). Under ordinary handling conditions decay would probably make the spinach unsalable before high CO_2 build-up (above 12 percent) could affect the flavor significantly.

Film in Relation to Percentage of Decay in Bags

The bags of spinach held at 70° F. were examined after 24, 48 and 72 hours and the lots in cold storage (40° F. and 32° F.) were examined after 1 week, 2 weeks, and 3 weeks. The spinach leaves were sorted out into two groups, decayed and non-decayed. These results are summarized in table 7.

Table 7. — Percent decay of spinach packaged in different films.

At 70° F. the spinach decayed very rapidly. In the first test after 24 hours, the spinach appeared sound and was acceptable. However, after 48 hours at 70° the breakdown ranged from 22 - 48 percent in cellophane films and as high as 84 percent in Pliofilm. In the second test after 24 hours, from 21 - 50 percent of the leaves in the cellophane bags and 95 percent in Pliofilm bags were decayed, and after 48 hours, 51 - 100 percent breakdown occurred. Only test 1 was examined after 72 hours and it showed breakdown ranging from 52 - 100 percent. The spinach in the first test was of much better quality than that in the second. There was approximately the same amount of decay in the first test after 48 hours as in the second test after 24 hours.

The perforated cellophane bags generally had as much decay as or more than their non-perforated counterparts. However, the perforated Pliofilm bags at 70° F. had consistently less decay than the non-perforated.

After one week at 40° F. there was 8.8 to 24.0 percent decay in the first test and 27.7 to 59.5 percent in the second test. At 32°F. decay in the first test, after one week storage was 2.5 to 9.1 percent and after three weeks 16 to 31 percent. The second test showed much higher percentages of decay in the same periods.

As previously mentioned, the decay percentage was obtained by weighing all decayed leaves no matter how small the decayed spot. This resulted in the inclusion of much healthy leaf tissue in the decay percentage figure. Commercially many of these decayed areas are not extensive enough to be recognized. Therefore the figures for percentage decay at 70° after 24 hours and 48 hours as given above are relatively high. In commercial practice, when the spinach is shipped to the stores it is generally about 40° and the temperatures in the stores during periods of handling packaged spinach are usually cooler than 70°. Any packages that are not sold during the day are placed in a cooler overnight and brought out for display the next morning. With such handling the development of decay is less than that obtained at a constant temperature of 70°.

Comparative Results

The six films are compared in table 8 for four characteristics; moistureproofness, permeability to CO_2, permeability to O_2, and incidence of decay within packages.

Table 8. — Comparison of different films in regard to average percent weight loss, average percent decay, average percent CO_2, and average percent O_2, for bags of spinach.

On examination of table 8 it is seen that there is no one film outstanding in all four categories. Except for moistureproof data there is no agreement between the ratings of any one cellophane film in test 1 with those in test 2. Pliofilm appears to be an undesirable film for spinach packaging because it allows development of unfavorable CO_2 and O_2 percentages and high decay. It was the most moistureproof film tested. The other films appear to be of approximately equal value as to decay CO_2 and O_2 relationships.

The spinach in the two tests appeared to be of different quality. This probably accounts for the great differences in decay found in the two tests. However, the relative differences in O_2 and CO_2 between films should have been the same in both tests. No such consistency was found and it is believed that differences in CO_2 and O_2 permeability between any of the cellophane films here tested were not as great as the differences introduced by variation in bag closure.

Practically all the decay noted in spinach is bacterial soft rot (4). This disease is a problem to spinach handlers, and especially to those without refrigeration. High humidity in the atmosphere of the bag, and close packing of the leaves produces ideal conditions for the development and rapid spread of the disease (3). Soft rot develops very rapidly in the temperature range from 75 - 80° F. In spinach packaging the leaves are usually "jammed and crammed" into the bag. This results in torn and frayed leaves in which infection first takes place. Water-soaked areas in the leaves soon appear, followed by rapid softening of the tissues which become wet, slimy, and mushy. In advanced stages the leaf is completely destroyed and foul, putrid odors are evident on opening the bag.

Smith (3) says that if diseased leaves are removed to dry air, the decay may be checked and the affected tissues become dry and brittle. Leaves would need to be spread out for this to occur. Since in a package, the leaves are bunched together, only the outer surface area of the bagged spinach would be exposed to moisture loss, even with the most permeable films. Cellulose acetate, which is very permeable, was not available for this test. However, acetate films have been used in similar tests in which it was found that the amount of decay was approximately the same as in the cellophane films.

Table 9 summarizes the comparative ratings of the six films used as bags for spinach packaging. The films are rated from 1 to 6. The bags which showed the least moisture loss, lowest decay, lowest CO_2 and highest O_2 are indicated in descending order in each column.

Table 9. — Comparative ratings of bags made of 6 different films as to moisture loss, carbon dioxide and oxygen concentrations and occurrence of decay.

Summary and Conclusions

These studies give the results of spinach prepackaging tests with bags of 6 types of transparent film. The films tested were Pliofilm and four kinds of cellophane, i.e., 450-MSAT-86, 450-MSAT-87, 300 PBDS, and 300 and 450 LSAT. Both perforated and non-perforated bags of each film were used.

Pliofilm was undesirable because of the high concentration of carbon dioxide, low oxygen and high decay which occurred within the packages. Generally all the cellophane bags at any one temperature were, for all practical purposes, equal in CO_2 and O_2 relationships and decay percentages.

Perforated films had a better CO_2 and O_2 relationship in the bag atmosphere, and did not show any significant moisture loss over the non-perforated bags. Perforation had little effect on the amount of decay in the cellophane films, but perforated Pliofilm at 70° F. showed a significantly lower percentage of decay.

The spinach of the first test in all films was salable for two days when kept at 70° F., while the spinach in the second test was salable for only 1 day. In the first test after one week at 40° F. the spinach in all films was barely salable, while that kept at 32° F. for one week was in fairly good condition. In the second test all 40° F. spinach was unsalable after one week while the 32° F. spinach was barely salable. The initial quality and condition of the spinach prior to packaging is very important in determining the subsequent amount of decay in the prepackaged product.

There was no one outstandingly suitable film for spinach prepackaging in these tests. The results indicate, however, that from a physiological standpoint anyone of the cellophane bags used in these tests, if refrigerated (32° - 40° F.) and perforated, would be a satisfactory film for prepackaging spinach.

Effect of Prepackaging, Storage Temperature, and Period in Storage on the Vitamin C and Carotene Content of Spinach

Three tests were run to determine the comparative retention of Vitamin C and carotene in prepackaged and bulk spinach.

In test 1, the prepackaged spinach was handled and bagged at the packaging plant in the regular manner. For a control, one bushel of bulk spinach was taken directly from the truck. The spinach was hauled to Beltsville separated into three lots and stored at 70°, 40° and 32°F. A sample of the bulk spinach used as a control was taken the next morning for analysis. Samples for analysis were also taken 48 and 72 hours after storage at 70°F., and after one week's storage at 40° and 32° F., and after 3 weeks at 32°. Samples from the three following treatments were analyzed for ascorbic acid: the bulk control, spinach in 450 LSAT non-perforated, and spinach in 450 MSAT 86 non-perforated bags.

The results are shown in table 10. The control was quite rich in ascorbic acid, initially having 111 mg/100 gm. sample. It lost 16, 23, and 39 percent after 48, 72 and 96 hours respectively at 70° F. The spinach in the bags had a much lower ascorbic acid percentage assay. While the control had 93 mg. per 100 gm. of spinach after 48 hours at 70° F. the spinach in the 450 LSAT and 450 MSAT 86 bags had only 43 mg. and 61 mg. per 100 gm. In the 72 hour samples, the control had 86 mg./100 gm., the 450 LSAT, 58 mg./100 gm. and the 450 MSAT 86 had 60 mg./100 gm. of spinach. After 96 hours because of the large amount of decay in the packaged lots only the control was suitable for sampling and had 68 mg./100 gm. of ascorbic acid. The control after one week at 40° F. had 93 mg./100 gm., while the lots in 450 LSAT and 450 MSAT 86 had 56 mg./100 gm. and 76 mg./100 gm. respectively. The 32° F. group showed a similar difference between the control and packaged lots.

Table 10. — Ascorbic Acid and carotene content of bulk and prepackaged spinach stored at different temperatures for varying periods. Test 1.

Carotene content did not vary significantly between the packaged and non-packaged groups.

The large difference in Vitamin C content between the bagged spinach and the check indicates that during handling the ascorbic acid is reduced in the leaves. At 32° F. there was little difference in Vitamin C content between the one week and three week samples. However, there was a marked difference at all temperatures, for all storage periods, between the control and the bagged spinach.

In order to determine whether the difference in ascorbic acid between the control and bagged spinach was due to the trimming, washing and bagging operations, another test was run in which the control was treated and bagged exactly as the other treatments. The spinach in the control lots, however, was removed from the bags immediately after bagging and handled in bulk. There were three treatments, the control which was trimmed, washed, bagged and removed from the bag, and the lots in 450 LSAT and 450 MSAT 86 which were handled regularly. The treatments were stored as in test 1 and sampled the same way. The spinach in this test was of lower quality and had a much lower vitamin C content than that used in test 1, as may be seen from the results summarized in table 11.

Table 11. — Ascorbic acid content of bulk and prepackaged spinach stored at different temperatures for varying periods. The bulk and prepackaged lots received identical trimming, washing and handling. Test 2.

These results do not show any appreciable differences in Vitamin C content between the "bulk" control and the two film treatments. The lots in the different films and the bulk check appear to have approximately the same ascorbic acid content and show approximately equivalent losses of Vitamin C over similar storage periods at the same temperatures. The bulk spinach does not show a greater percentage loss per day than the packaged as was shown in test 1.

The carotene content, as in test 1, did not vary with packaging treatment or storage temperature. These results indicated that washing and bagging caused losses of vitamin C. In order to determine the extent of such losses at various stages in the packaging process, a third test was run. In this test the spinach was similar in quality to the spinach of test 2. Nine treatments were used: (1) a control unwashed exactly as received, (2) bulk spinach trimmed, washed and centrifuged, (3) bulk spinach trimmed, washed, centrifuged, bagged and immediately removed from the bag, and (4 - 9) spinach packaged in the regular way in six different films.

The spinach was hauled to Beltsville after packaging and stored at 70°, 40°, and 32° F. as in the previous tests. The three controls were taken immediately to the laboratory and analyzed. The results are outlined in table 12.

Table 12. — Ascorbic acid content of bulk spinach handled in three different ways, and prepackaged spinach in six films stored at different temperatures for varying periods. Test 3.

The control which had no additional handling in the prepacking plant had 7 mg/100 gm. more ascorbic acid than the washed, trimmed and centrifuged lot, which in turn had 14 mg./100 gm. more ascorbic acid than the washed, trimmed, centrifuged, bagged and opened control. After 24 hours the unwashed control had 8 mg./100 gm. more ascorbic acid than the washed, trimmed, and centrifuged lot which had 7 mg./100 gm. more ascorbic acid than the washed, trimmed, centrifuged, bagged and opened treatment. There is thus indicated a loss of ascorbic acid at each handling step in the prepackaging process.

The data on the films show that the amount of ascorbic acid per 100 grams of spinach is approximately the same in all films stored at the same temperature for the same period of time, except Pliofilm at 70° F. for 24 hours. As noted previously spinach in Pliofilm for 24 hours at 70° was almost completely decayed. This may explain the drop to 16 mg/100 gm. value for Pliofilm after 24 hours at 70°.(Table 12) Apparently there is much ascorbic acid loss accompanying the development of decay, as is shown in the results of 16 days storage at 40° F.

In the first test although the ascorbic acid content in the control lots was higher than in the packaged lots the rate of loss was greater in the controls. This was not found in tests 2 and 3 which were designed to get an accurate check on this observation. In these tests the losses in the bulk, and in the bagged spinach per day, at the same temperature were approximately the same.

Conclusion:

An overall analysis of the data indicate that there is less ascorbic acid in bagged spinach than there is in bulk. The loss can be attributed to the trimming, washing, and bagging which causes bruising and tearing damage to the spinach leaves. Ascorbic acid is an unstable substance which is easily oxidized. Destruction of tissue cells by bruising and tearing during handling releases both oxidase enzymes and ascorbic acid which is readily oxidized. This is a strong argument for careful handling to reduce bruising and maceration of leaves. Sound leaves contain more vitamin C and are less subject to bacterial soft rot.

Carotene content did not vary appreciably with packaging, storage temperature or period in storage.

No significant difference in ascorbic acid was noted in the spinach prepackaged and held in any of the films used in these tests.

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Table 1. — Results of dipping spinach in solutions of various chlorine concentrations.

Treatment	cl - concentration before soak	cl - concentration after soak	pH before soak	pH after soak	Leaf Bacterial count before soak	Leaf Bacterial count after soak	Soak solution after soak	Percent decay 2nd day at 70° F.	Clorox injury
	p.p.m.	p.p.m.			per gm.	gm.		per cent	per cent
Tap H_2O	4	0	6.25	6.2	-	-	practically sterile	-	-
Control-Dry	-	-	6.2	6.2	6.9×10^8	-	-	-	-
1 Control-Dip	4	0	6.2	6.2	6.9×10^8	1.02×10^8	2.8×10^7	77.6	-
2 100 p.p.m.	100	8	8.2	6.5	"	2.4×10^7	sterile	79.7	-
3 1100 p.p.m.	1100	454	9.2	7.5	"	2.8×10^6	"	88.3	
4 3500 p.p.m.	3500	1846	9.6	8.0	"	1.1×10^6	"	36.7	3.0
5 5500 p.p.m.	5500	3834	9.8	8.5	"	7.7×10^5	"	40.4	10.0
6 11000 p.p.m.	11000	7313	10.1	8.6	"	1.5×10^5	"	?	88.8

Table 2. — Result of chlorine treatments on number of organisms and occurrence of decay

	Treatment *	Percent of organisms remaining on 1 gram of tissue after treatment	Percent of decay after 2 days at 70° F.	Percent injured (chlorine injury)
1	Control-15 min. soak in H_2O	14.7	77.6	-
2	100 p.p.m. cl_2	3.4	79.7	-
3	1,100 p.p.m. cl_2	0.4	88.3	-
4	3,500 p.p.m. cl_2	0.16	36.7	3.0
5	5,500 p.p.m. cl_2	0.11	40.4	10.0
6	11,000 p.p.m. cl_2	0.02	-	88.0

* Organisms per gram before treatment was 6.9×10^8

Table 3. — List of films used in spinach prepackaging tests.

Treatment	Film Type	Gauge	Perforation
1A	Cellophane MSAT 87	450	None
1B	" " "	450	Perforated
2A	Cellophane PBDS	300	None
2B	" "	300	Perforated
3A	Cellophane MSAT 86	450	None
3B	" " "	450	Perforated
4A	Cellophane LSAT	450	None
4B	" "	450	Perforated
5A	Cellophane LSAT	300	None
5B	" "	300	Perforated
6A	Rubber hydrochloride Pliofilm	75	None
6B	" " "	75	Perforated

Table 4. — Percent weight loss of spinach packaged in different films

Test	Film	Non Perforated Temperature and Storage Period									Average	Perforated Temperature and Storage Period									Average
		70°			40°			32°				70°			40°			32°			
		24 hr	48 hr	72 hr	1 wk.	2 wk.	3 wk.	1 wk.	2 wk.	3 wk.		24 hr	48 hr	72 hr	1 wk.	2 wk.	3 wk.	1 wk.	2 wk.	3 wk.	
1.	450 MSAT 87	-	0.66	2.12	0.83	-	2.18	0.66	-	0.65	1.18	-	0.66	2.33	0.67	-	3.02	0.83	-	1.33	1.39
	300 PBDS	-	1.17	2.94	1.15	-	3.61	0.66	-	1.18	1.78	-	1.17	2.35	1.00	-	3.68	0.99	-	2.15	1.82
	450 MSAT 86	-	0.33	1.50	1.00	-	2.00	0.65	-	0.66	1.02	-	0.50	1.47	0.32	-	2.01	0.50	-	1.15	0.99
	450 LSAT	-	2.16	4.63	1.83	-	5.60	1.68	-	3.48	3.23	-	2.19	4.07	2.69	-	7.95	2.33	-	4.67	3.98
	300 LSAT	-	2.16	4.78	2.50	-	6.74	1.66	-	4.05	3.65	-	2.36	5.08	3.33	-	9.02	2.14	-	5.42	4.56
	Pliofilm	-	0.00	1.59	0.38	-	1.59	0.77	-	0.78	0.85	-	0.39	1.59	1.18	-	1.59	0.77	-	1.20	1.12
2.	450 MSAT 87	0.00	0.50	-	0.50	1.18	-	0.32	0.65	0.66	0.50	0.65	1.16	-	1.15	1.85	-	0.66	0.52	1.49	1.07
	300 PBDS	0.68	1.48	-	1.35	2.20	-	1.05	1.17	1.86	1.40	0.83	1.54	-	2.14	2.54	-	1.33	0.82	1.85	1.58
	450 MSAT 86	0.34	0.67	-	0.33	1.00	-	0.34	0.66	1.54	0.70	0.67	0.68	-	1.15	1.03	-	0.67	0.81	1.70	0.96
	450 LSAT	1.48	2.55	-	3.18	4.55	-	1.45	2.16	3.52	2.69	1.69	3.22	-	3.98	5.04	-	2.16	3.00	3.68	3.25
	300 LSAT	2.05	3.81	-	4.35	5.04	-	2.43	3.03	4.05	3.34	2.13	3.81	-	4.63	5.79	-	2.85	3.62	4.41	3.89
	Pliofilm	0.00	0.73	-	0.38	0.74	-	0.37	0.36	0.00	0.37	0.37	0.75	-	0.75	1.54	-	0.37	0.74	0.78	0.76

Table 5. — Percent CO_2 accumulation in prepackaged spinach in which bags of different films were used.

Test	Film	Non-Perforated Temperature and Storage Period									Average	Perforated Temperature and Storage Period									Average
		70°			40°			32°				70°			40°			32°			
		24 hr	48 hr	72 hr	1 wk	2 wks	3 wks	1 wk	2 wks	3 wks		24 hr	48 hr	72 hr	1 wk	2 wks	3 wks	1 wk	2 wks	3wks	
1.	450 MSAT 87	-	5.7	10.2	3.4	-	3.1	1.8	-	1.5	6.43	-	2.7	3.0	0.8	-	0.3	0.3	-	0.7	1.3
	300 PBDS	-	4.2	8.4	1.0	-	2.5	2.0	-	1.6	6.32	-	2.4	3.8	0.6	-	0.5	0.4	-	0.4	1.35
	450 MSAT 86	-	8.8	5.6	2.2	-	3.7	1.7	-	1.5	3.91	-	3.5	3.1	0.8	-	0.7	0.9	-	0.6	1.6
	450 LSAT	-	6.1	7.1	2.4	-	4.6	1.4	-	1.7	3.88	-	2.7	3.6	0.9	-	1.7	0.7	-	0.5	1.68
	300 LSAT	-	6.1	7.6	2.3	-	3.0	2.0	-	1.9	3.81	-	2.9	1.9	1.1	-	0.7	0.6	-	0.4	1.26
	Pliofilm	-	8.4	20.8	4.4	-	8.2	2.4	-	5.8	8.33	-	3.0	4.6	1.2	-	2.2	1.2	-	1.6	2.30
2.	450 MSAT 87	8.4	8.9	-	2.9	3.5	-	1.5	1.0	2.0	4.02	1.9	2.6	-	0.9	0.7	-	0.3	0.6	0.6	1.00
	300 PBDS	8.8	7.2	-	2.8	2.7	-	1.0	1.2	1.4	3.58	2.6	2.5	-	0.8	0.6	-	0.2	0.8	0.5	1.06
	450 MSAT 86	9.6	9.7	-	2.5	3.0	-	1.8	0.9	1.9	4.2	2.5	3.4	-	1.5	0.7	-	0.6	0.7	0.5	1.32
	450 LSAT	6.2	5.8	-	2.6	1.7	-	0.8	1.1	0.8	2.62	2.2	1.7	-	0.9	0.9	-	0.5	0.7	0.3	1.06
	300 LSAT	5.1	6.5	-	2.1	1.8	-	1.0	1.4	0.7	2.66	0.9	1.5	-	1.6	0.2	-	0.2	0.4	0.9	0.81
	Pliofilm	14.6	16.4	-	8.2	6.4	-	3.0	2.8	5.8	8.17	1.8	3.6	-	1.6	0.4	-	0.6	0.8	0.4	1.24

Table 6. — Percent of O_2 in prepackaged spinach in which bags of different films were used.

Test	Film	Non Perforated Temperature and Storage Period									Average	Perforated Temperature and Storage Period									Average
		70°			40°			32°				70°			40°			32°			
		24 hr	48 hr	72 hr	1 wk	2 wks	3 wks	1 wk	2 wks	3 wks		24 hr	48 hr	72 hr	1 wk	2 wks	3 wks	1 wk	2 wks	3wks	
1.	450 MSAT 87	-	13.6	9.1	16.3	-	15.2	17.0	-	19.0	15.03	-	14.1	13.6	15.2	-	17.3	16.0	-	17.4	15.6
	300 PBDS	-	12.3	9.9	14.4	-	16.7	14.4	-	15.0	13.78	-	14.1	13.1	15.8	-	16.9	16.4	-	17.1	15.57
	450 MSAT 86	-	10.5	11.0	16.0	-	15.7	15.5	-	15.2	12.32	-	13.4	14.2	14.5	-	16.1	17.0	-	16.0	15.20
	450 LSAT	-	9.5	7.5	15.6	-	14.5	15.5	-	15.3	12.98	-	13.6	13.2	15.6	-	15.6	15.4	-	16.3	14.95
	300 LSAT	-	9.0	7.8	14.7	-	13.2	15.6	-	16.3	12.77	-	12.2	14.5	15.1	-	15.5	16.0	-	16.8	15.02
	Pliofilm	-	11.8	3.4	12.2	-	12.6	13.6	-	11.8	10.9	-	14.6	12.6	14.8	-	14.6	15.2	-	17.2	14.87
2.	450 MSAT 87	11.4	9.7	-	15.4	15.9	-	18.0	17.8	18.1	15.18	14.7	16.5	-	17.8	17.9	-	17.3	17.3	17.1	16.94
	300 PBDS	10.0	10.4	-	13.8	15.1	-	16.3	16.2	16.5	14.04	14.3	15.2	-	17.2	16.3	-	16.4	16.4	16.1	15.98
	450 MSAT 86	6.4	8.2	-	13.6	14.8	-	15.2	16.5	15.6	12.90	15.6	14.3	-	15.2	16.2	-	15.8	16.3	16.6	15.71
	450 LSAT	7.3	8.6	-	13.7	17.1	-	16.0	15.4	17.1	13.6	15.2	15.2	-	15.5	18.3	-	16.2	16.5	17.5	16.34
	300 LSAT	9.0	10.6	-	14.8	15.5	-	15.6	16.6	15.9	14.0	15.2	15.5	-	15.0	16.6	-	16.8	16.2	16.1	15.91
	Pliofilm	0.6	3.0	-	9.2	12.1	-	14.2	14.2	13.0	9.47	15.2	13.4	-	14.8	15.6	-	15.6	15.8	16.6	15.28

Table 7. — Percent decay of spinach packaged in different films

Test	Film	Non Perforated Temperature and Storage Period									Average	Perforated Temperature and Storage Period									Average
		70°			40°			32°				70°			40°			32°			
		24hr	48 hr	72 hr	1 wk	2 wks	3 wks	1 wk	2 wks	3 wks		24 hr	48 hr	72 hr	1 wk	2 wks	3 wks	1 wk	2 wks	3 wk	
	450 MSAT 87	-	32.5	67.5	8.8	-	92.1	4.0	-	26.4	38.55	-	48.4	72.5	14.1	-	93.6	3.2	-	31.4	41.68
	300 PBDS	-	24.1	77.5	14.2	-	88.4	3.3	-	16.7	37.36	-	22.7	72.5	14.4	-	88.2	3.7	-	18.1	35.52
	450 MSAT 86	-	25.0	52.5	13.9	-	79.6	9.1	-	18.0	33.02	-	46.2	62.5	18.7	-	95.3	5.6	-	28.8	40.88
1	450 LSAT	-	36.2	85.0	15.0	-	95.2	2.5	-	30.8	44.45	-	62.7	90.0	15.2	-	97.6	8.5	-	39.1	52.17
	300 LSAT	-	25.2	57.5	10.3	-	69.2	2.6	-	26.4	31.86	-	36.9	47.5	10.1	-	86.9	4.6	-	30.3	36.05
	Pliofilm	-	84.3	100.0	19.8	-	100.0	3.7	-	75.0	56.71	-	69.7	88.0	24.0	-	98.0	4.0	-	66.6	58.38
	450 MSAT 87	34.2	78.0	-	47.5	84.9	-	17.0	56.1	51.5	55.83	50.4	87.5	-	59.5	91.6	-	19.1	67.8	63.7	62.80
	300 PBDS	30.8	71.3	-	29.0	78.6	-	13.6	57.3	61.3	48.84	33.9	60.7	-	45.6	85.7	-	21.7	55.3	56.5	51.34
	450 MSAT 86	34.7	78.1	-	32.5	75.8	-	18.0	47.7	53.7	48.64	25.2	83.5	-	37.8	77.1	-	10.3	61.3	65.9	51.58
2	450 LSAT	27.0	51.0	-	35.1	84.1	-	13.0	45.0	53.8	51.50	27.7	64.5	-	38.9	85.6	-	20.5	63.6	62.6	51.91
	300 LSAT	23.8	63.6	-	27.7	69.4	-	13.7	39.1	35.1	38.91	21.2	61.2	-	39.7	75.0	-	17.4	35.6	44.1	42.03
	Pliofilm	95.0	100.0	-	42.4	81.1	-	18.5	43.1	45.7	60.83	29.4	80.0	-	50.2	84.8	-	26.0	50.9	71.4	56.10

Table 8. — Comparison of different films in regard to average percent weight loss, average percent decay, average percent CO_2, and average percent O_2, for bags of spinach.

Test	Film	Average percent weight loss for all temperature and all storage periods		Average percent of decay under all temperatures and time intervals		Average percent CO_2 under all temperatures and time intervals		Average percent of O_2 under all temperature and time intervals	
		Non perforated	Perforated	Non perforated	Perforated	Non perforated	Perforated	Non perforated	Perforated
1.	450 MSAT 87	1.18	1.39	38.55	41.68	6.43	1.3	15.03	15.6
	300 PBDS	1.78	1.82	37.36	35.52	6.32	1.35	13.78	15.57
	450 MSAT 86	1.02	0.99	33.02	40.88	3.91	1.6	12.32	15.20
	450 LSAT	3.23	3.98	44.45	52.17	3.88	1.68	12.98	14.95
	300 LSAT	3.65	4.56	31.86	36.05	3.81	1.26	12.77	15.02
	Pliofilm	0.85	1.12	56.71	58.38	8.33	2.30	10.90	14.83
2.	450 MSAT 87	0.50	1.07	55.83	62.80	4.02	1.00	15.18	16.94
	300 PBDS	1.40	1.58	48.84	51.34	3.58	1.06	14.04	15.98
	450 MSAT 86	0.70	0.96	48.64	51.58	4.2	1.32	12.90	15.71
	450 LSAT	2.69	3.25	51.50	51.91	2.62	1.06	13.60	16.34
	300 LSAT	3.34	3.89	38.91	42.03	2.66	0.81	14.0	15.71
	Pliofilm	0.37	0.76	60.83	56.10	8.17	1.24	9.47	15.28

Table 9. — Comparative ratings of bags made of 6 different films as to moisture loss, carbon dioxide and oxygen concentrations and occurrence of decay.

Test	Comparative standing	Average Weight loss		Average Percent of decay		CO_2		O_2	
		Non perforated	Perforated	Non perforated	Perforated	Non perforated	Perforated	Non perforated	Perforated
1.	1	PlioFilm	MSAT 86	300 LSAT	300 PBDS	300 LSAT	300 LSAT	450 MSAT 87	450 MSAT 87
	2	MSAT 86	PlioFilm	MSAT 86	300 LSAT	450 LSAT	450 MSAT 87	300 PBDS	300 PBDS
	3	MSAT 87	MSAT 87	PBDS	MSAT 86	450 MSAT 86	300 PBDS	450 LSAT	450 MSAT 86
	4	PBDS	300 PBDS	MSAT 87	MSAT 87	300 PBDS	450 MSAT 86	300 LSAT	300 LSAT
	5	450 LSAT	450 LSAT	450 LSAT	450 LSAT	450 MSAT 87	450 LSAT	MSAT 86	450 LSAT
	6	300 LSAT	300 LSAT	PlioFilm	PlioFilm	PlioFilm	PlioFilm	PlioFilm	PlioFilm
2.	1	PlioFilm	PlioFilm	300 LSAT	300 LSAT	450 LSAT	300 LSAT	MSAT 87	450 MSAT 87
	2	MSAT 87	MSAT 86	450 MSAT 86	300 PBDS	300 LSAT	450 MSAT 87	300 PBDS	450 LSAT
	3	MSAT 86	MSAT 87	300 MSAT 86	450 MSAT 86	300 PBDS	300 PBDS	300 LSAT	300 PBDS
	4	300 PBDS	300 PBDS	450 LSAT	450 LSAT	450 MSAT 87	450 LSAT	450 LSAT	300 LSAT
	5	450 LSAT	450 LSAT	450 MSAT 87	PlioFilm	450 MSAT 86	PlioFilm	450 MSAT 86	450 MSAT 86
	6	300 LSAT	300 LSAT	PlioFilm	450 MSAT 87	PlioFilm	450 MSAT 86	PlioFilm	PlioFilm

These ratings are based on averages obtained in each test, and are not absolute. They may be influenced by tightness of seal, breakage, imperfection of film, etc.

Table 10. — Ascorbic acid and carotene content of bulk and prepackaged spinach stored at different temperatures for varying periods. Test 1

Temperature and storage period		Control unwashed		Film 450 LSAT		Film 450 MSAT 86	
		Mg/100 gm.	% Loss	Mg/100 gm.	% Loss	Mg/100 gm.	% Loss
Sampled next morning held at 70°							
	Ascorbic	111					
	Carotene	5.67					
48 hours at 70°							
	Ascorbic	93	16	43	61	61	45
	Carotene	5.36	5.5	4.89	13.8	5.09	10.2
72 hours at 70°							
	Ascorbic	86	23	58	48	60	46
	Carotene	5.34	5.8	4.73	16.6	5.60	1.2
96 hours at 70°							
	Ascorbic	68	39				
	Carotene	5.46	3.7				
1 week at 40°							
	Ascorbic	93	16	56	50	76	32
	Carotene	5.60	1.2	4.92		5.14	9.4
1 week at 32°							
	Ascorbic	79	29	55	50	65	41
	Carotene	5.37	5.3	5.19		5.48	3.4
3 weeks at 32°	Ascorbic	93	16	48	57	66	41
	Carotene	5.64	0.5	5.14		5.64	0.5

Table 11. — Ascorbic acid and Carotene content of bulk and prepackaged spinach stored at different temperatures for varying periods. The bulk and prepackaged lots received identical trimming, washing and handling. Test 2.

Temperature and storage period		Control washed bagged, bags removed immediately	Film 450 LSAT	Film 450 MSAT 86
		Mg/100 gm.	Mg/100 gm.	Mg/100 gm.
Afternoon of day received				
	Ascorbic	54		
	Carotene	4.42		
24 hours at 70° F.				
	Ascorbic	36	37	32
	Carotene	4.35	4.42	4.59
48 hours at 70° F.				
	Ascorbic	28	29	27
	Carotene	4.27	4.40	4.48
1 week at 40° F.				
	Ascorbic	39	30	30
	Carotene	4.80	4.38	4.92
1 week at 31° F.				
	Ascorbic	45	44	42
	Carotene	4.34	4.30	4.29
2 weeks at 31° F.				
	Ascorbic	39	32	39
	Carotene	4.29	4.55	4.63
3 weeks at 31 - 32° F.				
	Ascorbic	39	28	37
	Carotene	4.55	4.57	4.95

Table 12. — Ascorbic acid content* of bulk spinach handled in three different ways, and prepackaged spinach in six films stored at different temperatures for varying periods. Test 3.

Temperature and storage period	Control			Film Bags					
	Not washed	Washed, trimmed and centrifuged	Washed, trimmed centrifuged bagged and opened immediately	1 450 MSAT87	2 PBDS	3 450 MSAT	4 450 LSAT	5 300 LSAT	6 Pliofilm
Afternoon of day received	76	69	55						
24 hours at 70° F.	53	45	38	33	21	25	29	25	16
48 hours at 70° F.			24	22	21	18	25	17	17
7 days at 40° F.			34	27	20	28	31	20	33
16 days at 40° F. (Badly wilted considerable decay)			14	10	13	10	16	14	-
7 days at 32° F.			40	37	35	38	36	35	36
17 days at 32° F.			34	23	24	24	29	29	27
21 days at 32° F.			25	15	18	18	25	21	20

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* Ascorbic acid given in mg/100 gm.